Comparative Analysis of the Performance of R22 with its Alternative Refrigerants

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Abstract - *In this paper explains the comparative performance analysis of vapour compression refrigeration system with three different refrigerants R22, R134A and R407C. At present, we have a large number of refrigerants available to us depending on the requirements of the particular refrigerating system. This paper is intended to serve as the comparative study of refrigerantsR-22 R-134A and R-407C has been carried from which the results has been obtained is plotted in the graph. The thermodynamic analysis of R134A, R407C and R22 has been presented. From the comparison of performance parameters it can be concluded that R407C is a potential HFC refrigerant replacement for new and existing systems presently using R22, R134A with minimum investment and efforts.*

Key Words: **Refrigerants, Vapour Compression Cycle, R22, R134A, R407C**

1. INTRODUCTION

Worldwide attempts are being made to phase out the production and consumption of Hydro Chloro-Fluorocarbon (HCFCs) and Chlorofluorocarbon (CFCs), as these chemicals are responsible for depletion of stratospheric ozone layer. Refrigeration, Air conditioning and heat pumps sectors are one of the principal users of these chemicals. As per Montreal Protocol (1987), refrigerant R22, the generally accepted and most suitable refrigerant for air conditioners must be phased out by 2030 by developed countries and by 2040 by developing countries because of its Ozone Depleting Potential. The phasing out of ozone depleting refrigerants has led to the quest for eco-friendly alternative refrigerants and substitutes for R22 have been developed.

Since R22 came into common use as a refrigerant in 1936, it has been applied in systems ranging from smallest window air-conditioners to the largest chillers and heat pumps. Individual equipment using this versatile refrigerant ranges from 2 kW to 33 MW in cooling capacity. No other refrigerant has achieved such a wide range of applications. However, R22 is one of a class of chemicals, HCFCs, being phased out due to the environmental hazard of ozone depletion.

Blends of the HFC refrigerants, in the first category of alternative refrigerants, have been considered the favorite candidates for R22 alternatives. HFCs are synthetic fluids entirely harmless to the ozone layer since they do not contain chlorine and hence have zero ODP. These fluids are the most used substitutes for CFCs and HCFCs. The research on refrigerant replacement for R22 has been one of hot topics in the refrigeration and air-conditioning industry. Many refrigerants were assessed through the Alternative Refrigerant Evaluation Program (AREP) as potential replacements for R22. The most promising alternative refrigerants that emerged were R410A, R407C, R134a, and R290.

2. VAPOUR COMPRESSION REFRIGERATION SYSTEM

Vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, where in the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems. Vapour compression refrigeration systems are available to suit almost all applications with the refrigeration capacities ranging from few Watts to few megawatts. A wide variety of refrigerants can be used in these systems to suit different applications, capacities etc. The actual vapour compression cycle is based on Evans-Perkins cycle, which is also called as reverse Rankin cycle.

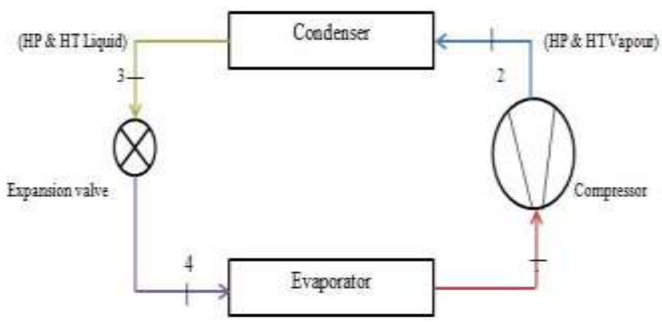

Fig -1: Vapour Compression Refrigeration System

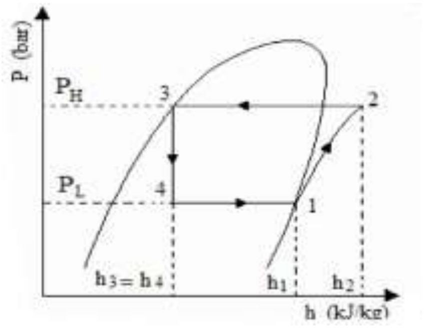

Fig -2: p-h Diagram

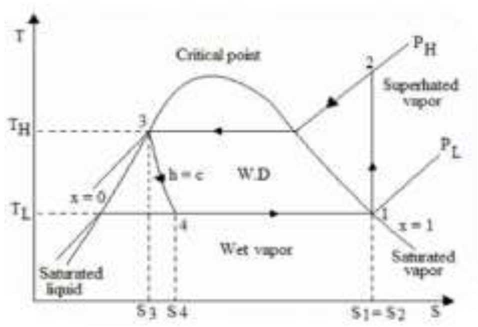

Fig -3: T-S Diagram

Vapour compression refrigeration system consists of the following four processes:

Process 1-2: Isentropic compression of saturated vapour in compressor

Process 2-3: Isobaric heat rejection in condenser

Process 3-4: Isenthalpic expansion of saturated liquid in expansion device

Process 4-1: Isobaric heat extraction in the evaporator

The COP of the system is given by:

$$COP = \frac{W}{Q} = \frac{(h1 - h4)}{(h2 - h1)} = \frac{(h1 - hf3)}{(h1 - h2)}$$

3. PHYSICAL PROPERTIES OF R-22, R-134A AND R407C

Table -1: PROPERTIES OF R-22, R-134A AND R407C

S.No	Property	R22	R134A	R407C
1	Chemical formula/ blend composition	CHClF2	CH2FCF3	23%R32+25%R125+52%R134a
2	Molar mass(kg/kmol)	86.486	102.3	86.204
3	Critical point temperature Tc(ºC)	96.145	101.6	86.034
4	Critical pressure (Pc) (bar)	49.9	40.593	46.298
5	Critical density(kg/m3)	523.84	511.90	484.23
6	Boiling point(ºC)	-40.810	-26.047	-43.8
7	Temperature glide at NBP (0C)	0	0	7.0
8	ODP	0.05	0	0
9	GWP	1810	1300	1770

4. MATERIALS AND METHODS

The refrigeration system is made up of four major components: condenser, evaporator, compressor and expansion device. In the evaporator, the liquid refrigerant vaporizes by absorbing latent heat from the material being cooled, and the resulting low pressure vapour refrigerant then passes from the evaporator to the compressor.

Compressor is the heart of the refrigeration system. It pumps and circulates refrigerant through the system, and supplies the necessary force to keep the system operating. It raises the refrigerant pressure and hence the temperature, to enable heat rejection at a higher temperature in the condenser. Condenser is a device used for removing heat from the refrigeration system to a medium which has lower temperature than the refrigerant in the condenser. The high pressure liquid refrigerant from the condenser passes into the evaporator through an expansion device or a restrictor that reduces the pressure of the refrigerant to low pressure existing in the evaporator. Expansion device regulates or controls the flow of liquid refrigerant to the evaporator.

5. RESULT & DISCUSSIONS

As we have compared the performance of R-22, R-134A and R-407C. For this we have plotted different sets of graph which shows the variation of different parameters from where we have got certain definite sets of results which are as follow –

1. **Pressure vs Temperature**: from chart-1 shows the graph between pressure and temperature we observed that the saturated vapour curve of R134A and R407C are near to the vapour pressure curve of R22, so we can say that they are similar to each other, therefore R134A and R407C can be treated as potential alternative refrigerants.

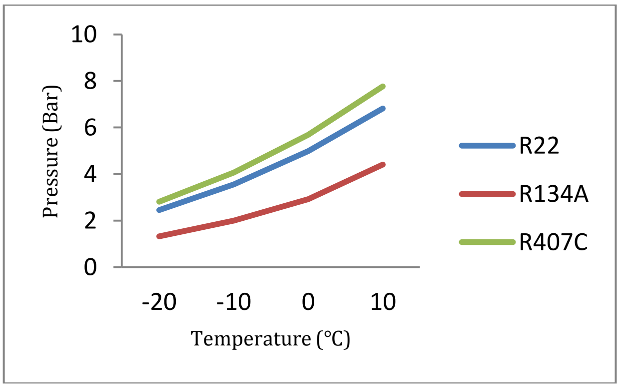

Chart-1: Pressure vs Temperature

2. **COP vs Cooling Capacity:** From chart-2 shows the graph between COP and cooling capacity, we observed that the COP of system increases with increasing cooling capacity. Below graph indicate that the R22 represents maximum COP and R134A represents minimum COP and the COP of R1407C close to the COP of R134A.

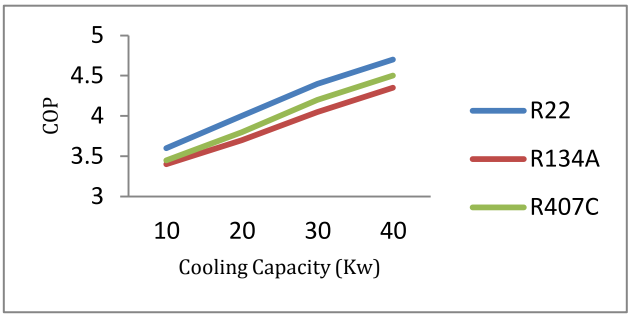

Chart-2: COP vs Cooling Capacity

3. **Mass Flow Rate vs Cooling Capacity:** from fig.3 shows graph between mass flow rate and cooling capacity, we observe that at high evaporator capacity, the refrigerant mass-flow rate through the system is increased. Below graph indicates that at maximum cooling capacity, the mass flow rate is minimum for R22 and maximum for R134A and R407C lies between R22 and R134A.

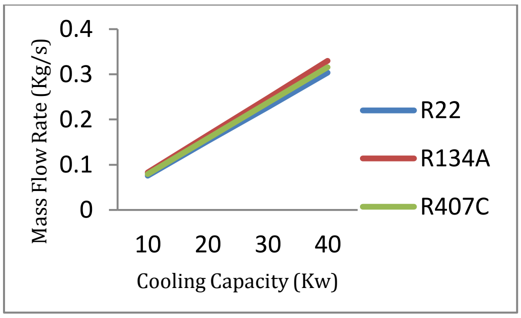

Chart-3: Mass Flow Rate vs Cooling Capacity

4. **Refrigerating Effect vs Evaporator Inlet Temperature:** From fig.4 shows the graph between refrigerating effect and evaporator inlet temperature, we observed that the evaporator temperature increases with increase in refrigerating effect. Below graph indicates that at maximum evaporator inlet temperature R22 and R134A has highest and lowest refrigerating effect, respectively.

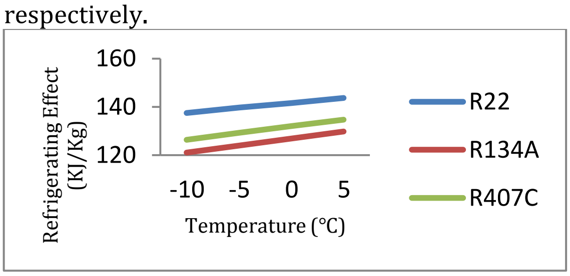

Chart-4: Refrigerating effect vs Evaporator Temp.

5. **Compressor Work vs Evaporator Inlet Temperature:** From chat-5 shows the graph between evaporator inlet temperature and compressor work, we observe that compressor work decreases with increase in evaporator temperature. Below graph indicates that R134A shows the highest values for compressor work and R407C near to R22.

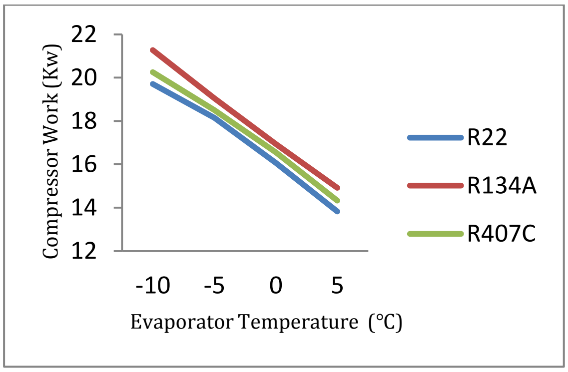

Chart -5: Compressor work vs Evaporator Temp.

6. **Refrigerating Effect vs Condenser Inlet Temperature:** From chart-6 shows the graph between refrigerating effect vs condenser temperature, we observed that the condenser temperature increases and decrease in cooling capacity. Below graph indicates that R22 shows the highest values for refrigerating effect in condenser temperature as compared to R134A and R407C.

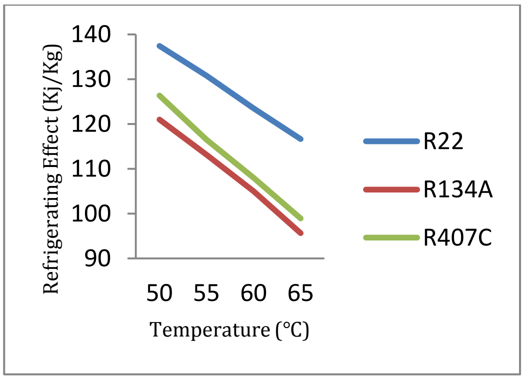

Chart -6: Refrigerating Effect vs Condenser Temp.

7. **Compressor Work vs Condenser Inlet Temperature:** From chart-7 shows the graph between condenser inlet temperature and compressor work, we observe that compressor work increase with increase in evaporator temperature. Below graph indicates that R134A shows the highest values for compressor work and R407C near to R22.

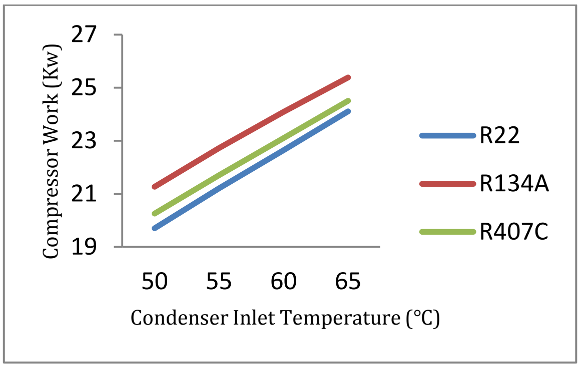

Chart -7: Compressor Work vs Condenser Temp.

8. **COP vs Evaporator Inlet Temperature:** From fig.8 shows graph between COP and evaporator inlet temperature, we observed that the inlet temperature of external fluid at evaporator increases, COP of system increases. Below graph indicate that R22 presents maximum and R134A presents minimum COP at inlet evaporator temperature of the external fluid and R407C near to the R22 curve.

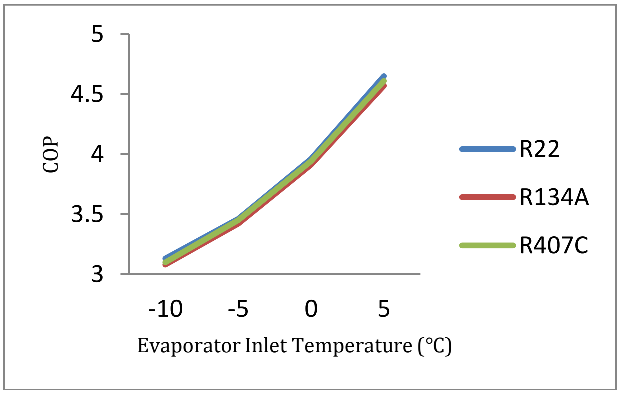

Chart -8: COP vs Evaporator Inlet Temp.

9. **COP vs Condenser Inlet Temperature:** From fig.9 shows the graph between COP and condenser inlet temperature, we observed that the inlet temperature of external fluid at condenser increases, COP of system decreases. Below graph indicates that the R22 represents maximum COP and R134A represents minimum COP and the COP of R407C near to R134A.

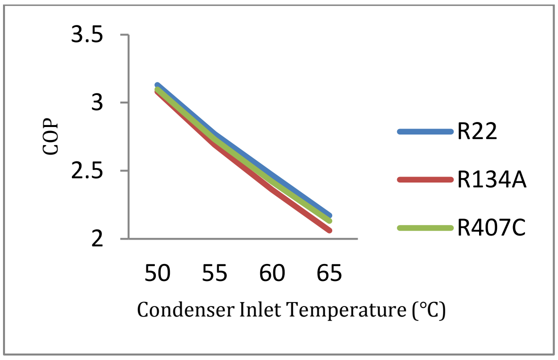

Chart -9: COP vs Condenser Inlet Temp.

10. **Mass Flow Rate vs Evaporator Inlet Temperature:** From fig.10 shows the graph between mass flow rate and evaporator temperature, we observed the inlet temperature of external fluid at evaporator increases refrigerant mass flow rate decreases. Below graph indicates that R22 presents minimum mass flow rate and maximum presents for R134A. R407C lies between R22 and R134A.

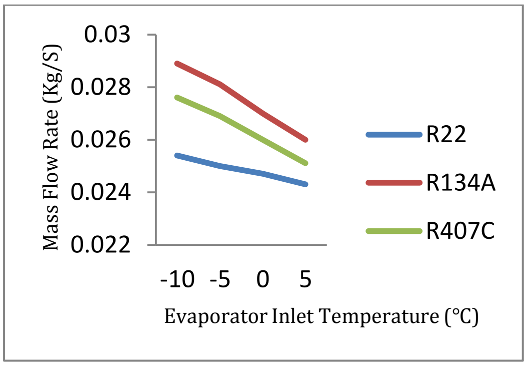

Chart -10: Mass Flow Rate vs Condenser Inlet

11. **Mass Flow Rate vs Condenser Inlet Temperature:** From the fig.11 shows the graph between mass flow rate and condenser inlet temperature, we observed that the inlet temperature of external fluid at condenser increases, refrigerant mass flow rate increases. Below graph indicate that R22 presents minimum mass flow rate and maximum presents for R134A. R407C lies between R22 and R134A.

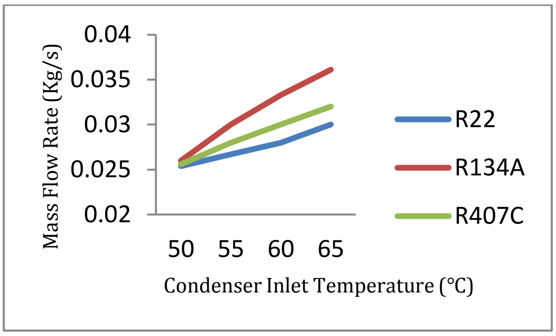

Chart -11: Mass Flow Rate vs Condenser Inlet Temp.

Table -1: Comparison of performance parameters for different refrigerants

Sr. no.	**Parameters**	R22	R134A	R407C
01.	COP	3.13	3.08	3.098
02.	Compressor Work (kW)	19.70	21.27	20.25
03.	Refrigerating Effect (KJ/kg)	137.39	121	126.3
04.	Mass Flow Rate (Kg/s)	0.45	0.542	0.512
05.	Condenser Pressure (bar)	19	13.1	21.8
06.	Evaporator Pressure (bar)	3.54	2	4.2
07.	Heat Transfer Rate (kW)	81.52	85.72	81.1

5. CONCLUSIONS

From the analysis done by using 7 factor analyses (COP, Refrigerating effect, compressor work, mass flow rate, evaporator pressure condenser pressure and heat transfer rate) and we concluded that performance of R134A and R407C are almost similar with R22.
By comparing R134A and R22 and we concluded that R134A has more costly as compared to R22 but R134A has less global warming potential (GWD) and zero ozone depletion potential (ODP).
If we compare R407C with R22 than it can be concluded that R407C is a potential HFC refrigerant replacement for R22. Also it has less costly in all respect and as well as zero ozone depletion potential (ODP) and less global warming potential (GWD).
Hence in this research paper conclude that the refrigerant R134A and R407C are alternative refrigerant for R22.

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